IMAGING APPARATUS AND COUPLING APPARATUS FOR USE THEREWITH

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to a imaging apparatus such as a video camera, and a coupling apparatus for use therewith. More particularly, the invention relates to a imaging technique for use in scientific measurement concerning fast moving bodies such as rockets, explosion, turbulence, electric discharge, movement of microbes under a microscope, and signal transfer of the brain and nervous system.

(2) Description of the Related Art

Conventionally, this type of apparatus includes a high-speed video camera (high-speed imaging apparatus) using CCD devices. A imaging apparatus optically coupling two or more cameras is known today. Such an apparatus is capable, for example, of determining a velocity field or a deformation field by operating a delayed synchronizing device to shift photographing timing, of performing simultaneous photography with lights of different wavelengths by installing a different optical filter in front of each camera, of performing high dynamic range photography by varying the sensitivity of each camera, or of performing

multi-wavelength photography or sensitivity-variable photography by freely changing beam split prisms with optical filters inserted to reflecting and transmitting planes thereof. A imaging apparatus incorporating these functions has been invented by Inventor herein and disclosed in Japanese Unexamined Patent Publication H10-233957 (see pages 4-6 and Figs. 1-4 of the publication).

However, the prior apparatus disclosed in the above publication has the following drawback. In order to exchange signals between camera heads (imaging units) and a control unit that performs an overall control of the cameras, a plurality of wires are required between the camera heads and the control unit. The more cameras are used, the more complicated the wiring becomes. Thus, where the cameras are used separately and independently of one another, for example, operation is hampered by the complicated wiring.

SUMMARY OF THE INVENTION

This invention has been made having regard to the state of the art noted above, and its object is to provide an improved imaging apparatus and an improved coupling apparatus for use therewith.

The above object is fulfilled, according to this invention, by a imaging apparatus having a plurality of image pickup devices, comprising a coupling device for optically

coupling optical images obtained from the plurality of image pickup devices, a timing control device for controlling image pickup timing of the image pickup devices, and an overall control device capable of bi-directional communication with at least one of the coupling device and the timing control device, for performing an overall control of the imaging apparatus, the coupling device having at least the timing control device mounted therein.

According to the imaging apparatus of this invention, the coupling device for optically coupling optical images obtained from the plurality of image pickup devices has at least the timing control device mounted therein. The overall control device for performing an overall control of the imaging apparatus is capable of bi-directional communication with at least one of the coupling device and the timing control device. Thus, the overall control device can process the imaging data optically coupling the optical images to obtain a photographic image. The overall control device can also control the plurality of image pickup devices through the timing control device. The communication for exchanging signals between the coupling device or timing control device and the overall control device is invariable regardless of the number of image pickup devices. Thus, this construction simplifies the bi-directional communication to and from the overall control device.

The device for enabling the bi-directional communication between the coupling device or timing control device and the overall control device may be wiring such as cables connected to the coupling device or timing control device and the overall control device. Alternatively, the coupling device or timing control device and the overall control device may have a function to transmit and receive electromagnetic wave, typically light, the bi-directional communication being carried out by means of electromagnetic wave. Then, bi-directional communication is performed with increased ease by means of electromagnetic wave.

The coupling device may be attachable to and detachable from each of the image pickup devices, and attachable to and detachable from the overall control device, and each of the image pickup devices may be attachable to and detachable from the overall control device. With this construction, one image pickup device may be connected directly to the overall control device, with the coupling device and other image pickup devices separated. Thus, photographs may be taken with one image pickup device independently. In this way, the imaging apparatus demonstrates increased flexibility.

The coupling device may have, mounted therein, a storage device for storing imaging data which are optical images obtained from the image pickup devices, or imaging

data optically coupling the optical images. With this construction, the coupling device can communicate such data to the overall control device as necessary. When, for example, the overall control device has a heavy load, the imaging data may remain stored in the storage device. When the overall control device has a light load, the imaging data stored in the storage device may be communicated to the overall control device.

Where each image pickup device acquires an optical image, the image pickup devices may be attached to have respective facing directions, to acquire light incident in the respective directions as optical images. In another technique, light may be divided into a plurality of components each received as an optical image. For the latter technique, the imaging apparatus may include a dividing device for deflecting light or dispersing light with a plurality of wavelengths to divide the light into a plurality of components, the image pickup devices acquiring the components of the light divided by the split device as optical images, respectively. The dividing device may be a half mirror for deflecting light, or a beam split prism for dispersing light with a plurality of wavelengths.

In another aspect of the invention, a coupling apparatus is provided for use with a imaging apparatus having a timing control device for controlling image pickup timing of a

plurality of image pickup devices, and an overall control device, wherein the coupling apparatus forms part of the imaging apparatus, the coupling apparatus having at least the timing control device mounted therein, and being arranged for optically coupling optical images obtained from the plurality of image pickup devices, and the overall control device performing an overall control of the imaging apparatus, and being capable of bi-directional communication with at least one of the coupling apparatus and the timing control device.

The coupling apparatus of this invention has at least the timing control device mounted therein for controlling image pickup timing of the image pickup devices. The overall control device which performs an overall control of the imaging apparatus is capable of bi-directional communication with at least one of the coupling apparatus and the timing control device. With the coupling apparatus acting as an intermediary, the overall control device can obtain a photographic image by processing the imaging data optically coupling the optical images, or control the plurality of image pickup devices through the timing control device.

In one embodiment of the invention, the coupling apparatus is attachable to and detachable from each of the image pickup devices, and attachable to and detachable from the overall control device.

With the coupling apparatus attachable to and detachable from each of the image pickup devices, and attachable to and detachable from the overall control device, one image pickup device and the overall control device may be separated and attached directly to the coupling apparatus. Thus, the coupling apparatus may be converted from a imaging apparatus having one image pickup device as known in the art to a imaging apparatus having a plurality of image pickup devices. The imaging apparatus according to this invention may be realized simply by using the conventional imaging apparatus having one image pickup device, which achieves increased flexibility.

In another embodiment, the coupling apparatus includes a storage device mounted therein for storing imaging data optically coupling the optical images.

With the storage device mounted in the coupling apparatus for storing imaging data optically coupling the optical images, the coupling apparatus can communicate such data to the overall control device as necessary.

In another embodiment, the coupling apparatus includes a dividing device mounted therein for deflecting light or dispersing light with a plurality of wavelengths to divide the light into a plurality of components, the image pickup devices acquiring the components of the light divided by the split device as optical images, respectively.

With the dividing device mounted in the coupling apparatus for deflecting light or dispersing light with a plurality of wavelengths to divide the light into a plurality of components, the respective image pickup devices acquire the components of the light divided by the dividing device as optical images.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of illustrating the invention, there are shown in the drawings several forms which are presently preferred, it being understood, however, that the invention is not limited to the precise arrangement and instrumentalities shown.

Fig. 1 is a block diagram showing an outline of a imaging apparatus according to this invention;

Fig. 2 is a block diagram showing the imaging apparatus in a state of performing three-dimensional imaging;

Fig. 3 is a block diagram of the imaging apparatus constructed as the single plate type;

Fig. 4 is a flow chart of a photographic method using the imaging apparatus according to this invention; and

Fig. 5 is a block diagram showing an outline of a modified imaging apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of this invention will be described in detail hereinafter with reference to the drawings.

Fig. 1 is a block diagram showing an outline of a imaging apparatus according to this invention. Fig. 2 is a block diagram showing the imaging apparatus in a state of performing three-dimensional photography. This embodiment will be described by taking for example what is known as a three-plate imaging apparatus having three imaging cameras. However, the invention is applicable to any such apparatus having a plurality of imaging cameras. That is, the number of cameras may be two, four or more.

As shown in Fig. 1, the apparatus in this invention, broadly, includes three imaging cameras 1A, 1B and 1C, a docking unit 2 for optically coupling optical images provided by the cameras 1A, 1B and 1C, and a camera controller 3 for performing an overall control of the apparatus. The imaging cameras 1A, 1B and 1C correspond to the image pickup devices of this invention. The docking unit 2 corresponds to the coupling device of this invention. The camera controller 3 corresponds to the overall control device of this invention. The docking unit 2 corresponds also to the coupling apparatus of this invention.

The docking unit 2 is constructed attachable to and detachable from the respective cameras 1A, 1B and 1C, and

attachable to and detachable from the camera controller 3. Each of the cameras 1A, 1B and 1C and the camera controller 3 are attachable to and detachable from each other.

Specifically, each of the cameras 1A, 1B and 1C has two cables connected thereto, the other ends of the cables being connected to connectors. As shown in Fig. 1, the camera 1A is connected to connectors 10a and 10b through the cables, the camera 1B is connected to connectors 11a and 11b through the cables, and the camera 1C is connected to connectors 12a and 12b through the cables. In Figs. 1 and 2, and in this embodiment, the number of cables connected to each camera 1A, 1B or 1C is two. However, the number of cables is not limited to two, but may be varied as appropriate according to designs of the apparatus or photographic conditions.

The docking unit 2 has connectors 20a-22a and 20b-22b arranged in positions corresponding to the connectors 10a-12a and 10b-12b, respectively. The connector 10a of the camera 1A is electrically connectable to the connector 20a of the docking unit 2. The connector 10b of the camera 1A is electrically connectable to the connector 20b of the docking unit 2. The connector 11a of the camera 1B is electrically connectable to the connector 21a of the docking unit 2. The connector 11b of the camera 1B is electrically connectable to the connector 21b of the docking unit 2. The

connector 12a of the camera 1C is electrically connectable to the connector 22a of the docking unit 2. The connector 12b of the camera 1C is electrically connectable to the connector 22b of the docking unit 2.

Each of the cameras 1A, 1B and 1C has a main body attachable to the docking unit 2. As shown in Figs. 2 and 3, the cameras 1A, 1B and 1C have lenses 13, 14 and 15, respectively, which are used only when the cameras 1A, 1B and 1C are used individually as separated from the docking unit 2. When the main bodies of cameras 1A, 1B and 1C are attached to the docking unit 2 as shown in Fig. 1, the lenses 13-15 are detached from the main bodies of cameras 1A, 1B and 1C.

The camera controller 3 also has two cables connected thereto, the other ends of the cables being connected to connectors 30a and 30b. The docking unit 2 has connectors 23a and 23b arranged in positions corresponding to the connectors 30a and 30b, respectively. The connector 30a of the camera controller 3 is electrically connectable to the connector 23a of the docking unit 2. The connector 30b of the camera controller 3 is electrically connectable to the connector 23b of the docking unit 2.

With the cameras 1A, 1B and 1C, docking unit 2 and camera controller 3 constructed as described above, as shown in Fig. 3, for example, the camera 1A and camera

controller 3 may be connected directly to each other, with the docking unit 2 and other cameras 1B and 1C separated, to take photographs with one camera 1A. That is, the apparatus may act as a single plate imaging apparatus. For performing photography as in Fig. 3, the connectors 10a and 10b of the camera 1A are disconnected from the connectors 20a and 20b of the docking unit 2, and the camera 1A is separated from the docking unit 2 and other cameras 1B and 1C. Further, the connectors 30a and 30b of the camera controller 3 are disconnected from the connectors 23a and 23b of the docking unit 2, and the camera controller 3 is separated from the docking unit 2 and other cameras 1B and 1C. The connector 10a of the camera 1A is connected to the connector 30a of the camera controller 3, and the connector 10b of the camera 1A to the connector 30b of the camera controller 3, thereby connecting the camera 1A directly to the camera controller 3. Then, the lens 13 is attached to the camera 1A.

The cameras 1A, 1B and 1C may be separated from the docking unit 2, with the lens 13 attached to the camera 1A, the lens 14 attached to the camera 1B, and the lens 15 attached to the camera 1C. Then, as shown in Fig. 2, a photographic subject M may be photographed with the cameras 1A, 1B and 1C from three directions, to perform three-dimensional photography. If the cables are too short

for this purpose, extension cables may be connected thereto.

Next, a specific construction of the docking unit 2 will be described. The docking unit 2 has a built-in lens 24 facing the photographic subject M, and a synchronous control circuit 25, a coupling circuit 26 and a storage circuit 27 arranged in a region adjacent the camera controller 3. The docking unit 2 further includes a beam split prism 28 for dispersing light received from the photographic subject M through the lens 24, to divide the light into components traveling in three directions. The synchronous control circuit 25 corresponds to the timing control device of this invention. The storage circuit 27 corresponds to the storage device of this invention. The beam split prism 28 corresponds to the dividing device of this invention.

The synchronous control circuit 25 controls the cameras 1A, 1B and 1C while synchronizing the timing thereof. Three cables are connected to an end of the synchronous control circuit 25 for connection to the cameras 1A, 1B and 1C, the other ends of these cables being connected to the connectors 20a-22a of the docking unit 2, respectively. That is, the synchronous control circuit 25 is connected through the cables to the connectors 20a-22a connected to the cameras A1, 1B and 1C. A cable is connected to the other end of the synchronous control circuit 25 for connection to the camera controller 3, the other end of the cable being connected to the

connector 23a of the docking unit 2. That is, the synchronous control circuit 25 is connected through the cable to the connector 23a connected to the camera controller 3.

The coupling circuit 26 obtains imaging data by optically coupling optical images received from the cameras 1A, 1B and 1C. Three cables are connected to an end of the coupling circuit 26 for connection to the cameras 1A, 1B and 1C, the other ends of these cables being connected to the connectors 20b-22b of the docking unit 2, respectively. That is, the coupling circuit 26 is connected through the cables to the connectors 20b-22b connected to the cameras 1A, 1B and 1C. A cable is connected to the other end of the coupling circuit 26 for connection to the camera controller 3, the other end of the cable being connected to the connector 23b of the docking unit 2. That is, the coupling circuit 26 is connected through the cable to the connector 23b connected to the camera controller 3.

The storage circuit 27 stores imaging data, i.e. optical images, received from the cameras 1A, 1B and 1C, or the imaging data provided by the coupling circuit 26 after optically coupling the optical images. The coupling circuit 26 and storage circuit 27 are interconnected through a cable to be capable of bi-directional communication.

The beam split prism 28 disperses light with a plurality of wavelengths to divide the light into components

traveling in three directions. The beam split prism 28 is disposed in the docking unit 2 for directing divided components of light to enter the camera 1A, camera 1B and camera 1C, respectively. With this arrangement, each camera 1A, 1B or 1C acquires, as an optical image, each component of light divided by the beam split prism 28.

Next, a photographic method using the apparatus in this embodiment will be described with reference to the flow chart of Fig. 4.

(Step S1) Condition Setting

Photographic conditions for the cameras 1A, 1B and 1C are set from the camera controller 3. The photographic conditions include, for example, photographing intervals indicative of time per unit frame (second per frame), an exposure time indicative of time of light incidence during the photographing intervals, a lighting time indicative of time for illuminating the photographic subject M continuously or intermittently, and lighting intensity which is the intensity of light illuminating the photographic subject M.

Data of photographic conditions set is inputted to the synchronous control circuit 25 through the cable, the connector 30a of the camera controller 3 and the connector 23a of the docking unit 2. The data of photographic conditions inputted to the synchronous control circuit 25 is inputted to the cameras 1A, 1B and 1C. For this purpose, a branched

trigger signal is transmitted through the cable, the connector 20a of the docking unit 2 and the connector 10a of the camera 1A. Another branched trigger signal is transmitted through the cable, the connector 21a of the docking unit 2 and the connector 11a of the camera 1B. The remaining branched trigger signal is transmitted through the cable, the connector 22a of the docking unit 2 and the connector 12a of the camera 1C.

(Step S2) Photography Standby State

The cameras 1A, 1B and 1C are kept on standby until a trigger signal is inputted to the camera 1A from a sensor not shown.

(Step S3) Input Trigger Signal

When a trigger signal is inputted to the camera 1A, this trigger signal is inputted to the synchronous control circuit 25 through the cable, the connector 10a of the camera 1A and the connector 20a of the docking unit 2. The trigger signal inputted to the synchronous control circuit 25 is transferred to the cameras 1B and 1C. For this purpose, one branched trigger signal is transmitted through the cable, the connector 21a of the docking unit 2 and the connector 11a of the camera 1B. The other branched trigger signal is transmitted through the cable, the connector 22a of the docking unit 2 and the connector 12a of the camera 1C.

In this embodiment, the trigger signal is inputted to

the camera 1A, and then to the cameras 1B and 1C through the synchronous control circuit 25. Alternatively, the trigger signal may first be inputted to the synchronous control circuit 25, and thereafter simultaneously to the cameras 1A, 1B and 1C.

(Step S4) Photography

After the trigger signal is inputted also to the cameras 1B and 1C, the cameras 1A, 1B and 1C start photography on the photographic conditions set. The light from the photographic subject M is inputted to the beam split prism 28 via the lens 24. The beam split prism 28 disperses the incident light to travel in the three directions. The divided components of light enter the camera 1A, camera 1B and camera 1C, respectively. The cameras 1A, 1B and 1C acquire the divided components of light as optical images.

(Step S5) Store and Join Photographic Data

Photographic data of optical images obtained from the respective cameras 1A, 1B and 1C are stored in the storage circuit 27 through the coupling circuit 26. To describe this process particularly in relation to the camera 1A, imaging data which is an optical image obtained from the camera 1A is inputted to the coupling circuit 26 through the cable, the connector 10b of the camera 1A and the connector 20b of the docking unit 2. The imaging data inputted to the coupling circuit 26 is inputted to and stored

in the storage circuit 27 through the cable. The imaging data from the cameras 1B and 1C are stored through the same procedure, which will not be described.

The imaging data stored in the storage circuit 27 are read from the storage circuit 27 and inputted to the coupled circuit 26 through the cable as required. The coupling circuit 26 optically couples the imaging data inputted. The imaging data optically coupled may be stored in the storage circuit 27 again.

In this embodiment, the imaging data of optical images obtained from the respective cameras 1A, 1B and 1C are once stored in the storage circuit 27 through the coupling circuit 26, and are then read and optically coupled by the coupling circuit 26. Alternatively, the coupling circuit 26 may optically couple the optical images obtained from the cameras 1A, 1B and 1C to obtain imaging data, and store the coupled imaging data in the storage circuit 27.

(Step S6) Display Photographic Image

The imaging data coupled by the coupling circuit 26 is inputted to the camera controller 3 through the cable, the connector 23b of the docking unit 2 and the connector 30b of the camera controller 3. The imaging data inputted to the camera controller 3 is displayed on a monitor not shown, or printed by a printer not shown, as a photographic image.

According to the embodiment described above, the

docking unit 2 which optically couples optical images obtained from the plurality of (e.g. three) cameras 1A, 1B and 1C includes at least the synchronous control circuit 25 for controlling the image pickup timing of the cameras 1A, 1B and 1C. The camera controller 3 which performs an overall control of this apparatus is constructed capable of bi-directional communication with the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2. The camera controller 3 processes the imaging data optically coupling the optical images to obtain a photographic image. The camera controller 3 can also control the plurality of cameras 1A, 1B and 1C through the synchronous control circuit 25. The communication for exchanging signals between the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2 and the camera controller 3 is invariable regardless of the number of cameras 1A, 1B and 1C (three in this embodiment). Thus, this embodiment simplifies the bi-directional communication to and from the camera controller 3.

In this embodiment, cables serve as the device for enabling the bi-directional communication between the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2 and the camera controller 3. The number of cables between the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2 and the camera control-

ler 3 is invariable regardless of the number of cameras 1A, 1B and 1C (i.e. three in this embodiment).

That is, on the part of the docking unit 2 having the described construction, the docking unit 2 acts as an intermediary for allowing the camera controller 3 to obtain a photographic image by processing the imaging data optically coupling the optical images, and to control the plurality of cameras 1A, 1B and 1C through the synchronous control circuit 25.

The docking unit 2 is constructed attachable to and detachable from the cameras 1A, 1B and 1C, and also attachable to and detachable from the camera controller 3. Furthermore, each cameras 1A, 1B or 1C is attachable to and detachable from the camera controller 3. With this construction, as shown in Fig. 3, one camera, e.g. camera 1A, may be connected directly to the camera controller 3, with the docking unit 2 and other cameras 1B and 1C separated. Thus, photographs may be taken with one camera 1A. In this way, the imaging apparatus demonstrates increased flexibility.

The docking unit 3 has, mounted therein, the storage circuit 27 for storing imaging data of optical images obtained from the respective cameras 1A, 1B and 1C, or imaging data optically coupling the optical images. Thus, the docking unit 3 can communicate such data to the camera

controller 3 as necessary. When, for example, the camera controller 3 has a heavy load, the imaging data may remain stored in the storage circuit 27. When the camera controller 3 has a light load, the imaging data stored in the storage circuit 27 may be communicated to the camera controller 3.

This invention is not limited to the foregoing embodiment, but may be modified as follows:

(1) In the foregoing embodiment, the device for enabling the bi-directional communication between the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2 and the camera controller 3 comprises the cables capable of bi-directional communication. Such cables may be replaced by two types of cables, one capable of communication only to the camera controller 3 and the other capable of communication only from the camera controller 3. In this case, the number of cables between the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2 and the camera controller 3 is twice that of the described embodiment. Further, the device for enabling the bi-directional communication between the synchronous control circuit 25 and coupling circuit 26 in the docking unit 2 and the camera controller 3 is not limited to cables, but may be a communication device used widely. For example, the docking unit 2 or synchronous control circuit 25 and the

camera controller 3 may have a function to transmit and receive electromagnetic wave, typically light, so that bi-directional communication is carried out by electromagnetic wave. Then, bi-directional communication is performed with increased ease by means of electromagnetic wave.

(2) In the foregoing embodiment, a beam split prism that disperses light with a plurality of wavelengths is used as a device for dividing light into a plurality of components. This device is not limited to a beam split prism as long as it disperses light with a plurality of wavelengths. Instead of dispersing light with a plurality of wavelengths, light may be deflected into a plurality of components. A device for deflecting light includes a half mirror, for example. It is of course possible to combine a device, typically a beam split prism, for dispersing light with a plurality of wavelengths, and a device, typically a half mirror, for deflecting the light.

(3) In the foregoing embodiment, the docking unit 2 has, mounted therein, a beam split prism that disperses light with a plurality of wavelengths as a device for dividing light into a plurality of components. It is not absolutely necessary to divide light into a plurality of components. As shown in Fig. 5, the same photographic subject M may be photographed with image pickup cameras 1A, 1B and 1C attached to have respective facing directions, to acquire light

incident in the respective directions as optical images. In this case, the light enters the lens 13 of camera 1A, the lens 14 of camera 1B and the lens 15 of camera 1C without being divided.

(4) In the foregoing embodiment, the synchronous control circuit 25 controls the timing of the cameras 1A, 1B and 1C to take photographs simultaneously. A delay circuit may be provided in place of the synchronous control circuit to shift photographic timing, thereby to obtain a velocity field or a deformation field. Different optical filters may be placed in front of the cameras 1A, 1B and 1C to perform simultaneous photography with light of different wavelengths. High dynamic range photography may be carried out by varying the sensitivity of each of the cameras 1A, 1B and 1C. Multi-wavelength photography or variable sensitivity photography may be carried out by changing beam split prisms with optical filters inserted into reflection and transmission surfaces thereof. Furthermore, these functions may be combined as appropriate. The delay circuit corresponds to the delay device of this invention.

This invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification, as indicating the scope of the invention.